ONR RESEARCH PROJECT

ANNUAL PROGRESS REPORT

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CONTRACTOR: Duke University

PRINCIPAL INVESTIGATOR: J. G. Pratt

Assistants: Gustav Kramer, Ursula v. St. Paul

TITLE OF PROJECT: Research on animal orientation, with emphasis on the phenomenon of homing in pigeons.

PROBLEM

Background

The problem presented by the phenomenon of homing in pigeons has been brought into sharp scientific focus chiefly through the work of Dr. G.V.T. Matthews of Cambridge University and that of Dr. Gustav Kramer and his associates of the Max-Planck-Institut in Wilhelmshaven, Germany. In America, pigeon homing studies are being actively pursued by Dr. Harold B. Hitchcock of Middlebury College, as well as in the work at Duke University covered by this report.

The investigations thus far have largely cleared up prevailing misconceptions about the problem. Some of these misconceptions were hypotheses with more or less scientific standing that had been put forward as explanations of homing. Chief among these were those of random searching, of memory of kinesthetic impressions from the outward journey, and of sensitivity to a combination of the earth's magnetic field and an effect of the earth's rotation. Random searching is disproved as an adequate hypothesis by the fact that pigeons may be seen to start toward home before they are out of sight at the release point. This type of observation has been made so successfully by all the recent investigators that the departure flights have become the most important source of information in pigeon homing experiments. The kinesthesia hypothesis has been rendered quite

improbable by the fact that birds hauled in a rotating drum a part as quickly and as close to the home direction as birds carried in the usual manner in crates. Likewise, the hypothesis of sensitivity to the earth's magnetic field is made very improbable by the fact that birds with magnets attached to their wings and birds carrying neutral weights show no difference in homing orientation. The strongest evidence against the latter two hypotheses was that obtained by Matthews.

Matthews offered a new hypothesis of distance orientation based upon sun navigation. He has published a number of experimental articles during the past three years in which this hypothesis has been formulated and his findings have been interpreted as supporting it. The chief support for sun navigation is claimed from the fact, upon which all investigators agree, that departure flights are more nearly random when the sun is concealed by clouds than when the sky is clear. For reasons that will be clear from results to be summarized below, it seems doubtful that the sun navigation hypothesis can explain the important fact of the initial choice of the home direction, though the sun's position may serve as a reference point to guide the flight after the choice of direction has been made.

Objectives

At the present stage of the Duke homing investigation, the objectives of the research are:

1. To test Matthews' sun navigation hypothesis more thoroughly.

2. To consider and test new hypotheses of homing that can be brought to controlled study.

3. To isolate release-orientation factors from those concerned with course-holding.

4. To develop a method for studying homing orientation under conditions more closely approaching a laboratory situation.

SUMMARY OF RESULTS

The pigeon homing project at Duke University was initiated about the first of January, 1952, and the ONR contract became effective on October 15, 1953. There was, therefore, approximately a year of active research efforts before the period covered by the present annual progress report; and the report period itself consists of nine and a half months of research supported entirely by Duke University funds, and two and a half

months with additional support from ONR. These periods may be summarized separately, as they represent logical stages of development in the research.

The preliminary period (1952)

This was a stage of acquiring stock and facilities and of attempting to master a technique for successfully observing homing orientation. The progress on the material side was satisfactory. Old birds for breeding stock were furnished by interested pigeon fanciers, and young birds for experimental releases were obtained from the Signal Corps Pigeon Center at Ft. Monmouth and from other sources.

The first efforts to find a satisfactory experimental technique were not successful, however. The procedures described in the literature left the pigeons completely confused when they were released in homing tests. During this period the pigeons characteristically circled or flew at random near the release point for several minutes, and such vanishing points as were recorded showed no relation to the home direction. Also, losses were heavy, and the procedure defeated itself before releases were made at a sufficient distance for a crucial test of homing. Comparable circling just after release had been reported by both Matthews and Hitchcock, and indeed, it was generally held that pigeons had to circle before they could show homeward orientation.

The work of Kramer and his associates in Germany, however, was characterized by immediate departures without circling. The first period of the Duke investigations ended as Dr. Kramer accepted an invitation to spend a month at Duke in order to introduce his methods into the pigeon homing project of the Parapsychology Laboratory.

The first period of productive research (Jan.-Sept., 1953)

Dr. Kramer spent the month of January, 1953, at Duke University. We changed the method of handling the pigeons to conform more closely with that used at Wilhelmshaven, and at the end of the month we conducted a test release at a distance of 147 miles with pigeons that had previously made only three non-directional flights from a distance of 10 miles. Six separate releases were made, one of a single bird nine months of age, and the others birds of from three to five months of age in groups of three or four. Every release vanished from sight in the half of the circle toward home. The nine-month-old bird homed in four hours, six of the young birds were back in from six to eight hours on the day of release, and two more came in later. By the end of his

visit, Dr. Kramer felt confident that the pigeon stock available at Duke could be used to get results similar to those obtained at the Max-Planck-Institut. The results of this joint pilot experiment are summarized in the first publication listed at the end of this report.

After Dr. Kramer's visit, a series of three experiments were conducted during the spring and summer. The primary object in these experiments was to compare the homing orientation of pigeons for whom the release was the very first one out of sight of the loft (untrained group) with that of other pigeons that had been given three preliminary short-distance releases from different directions (trained group). The first experiment was an exploratory study using group releases at 147 miles in which only two birds without previous releases were included. The other two experiments were tests comparing trained and untrained pigeons in single releases at 75 miles. In these two tests, 21 untrained pigeons and 23 trained pigeons were used. Both groups showed a statistically significant tendency to vanish in the home half of the circle, 18 of the untrained birds and 20 of the group with previous short-distance releases going out of sight less than 90 degrees from the home line, with no appreciable difference between the two groups in accuracy of orientation.

A second point of special interest was that of how the trained and untrained birds would compare in success in returning home. Here, again, there was no appreciable difference, each group showing approximately 50% homing success.

Still a third point was concerned with the comparison of different strains of homing stock used in these experiments. Some of the birds were obtained from sources which provided no record of the homing performance of the parents, whereas other birds were from parents selected for outstanding homing ability. The two strains showed no difference in the accuracy of orientation at the release point, but there was a significant difference in homing success. The results, in other words, indicated that hereditary factors were reflected more clearly in the percentage of birds reaching the loft than in the number initially starting out toward home.

After these experiments were completed, a report by Matthews dealing with orientation of untrained pigeons was published. Our results agreed in that the pigeons in both investigations showed homeward orientation at the release point. They were different, however, in the amount of homing success achieved. In Matthews' work only one pigeon out of 39 released returned to the loft, whereas in the three Duke experiments 13 out of 25 homed successfully. The percentage of returns obtained by Matthews would, of course, rule out the regular use of untrained

pigeons as an impractioable procedure. On the other hand, the returns of better than 50% obtained at Duke led us to work with untrained pigeons in many of the experiments done since that time. This method may offer advantages over the use of either directional training (as used by Matthews) or preliminary short-distance, non-directional releases (introduced by Kramer and his associates).

Start of work under the ONR contract (Oct.-Dec., 1953)

In September, Dr. R. H. Thouless, experimental psychologist of Cambridge University, came to Duke University for a semester of research in the Parapsychology Laboratory. This visit offered an opportunity to relate the Duke pigeon work more closely to that done by Dr. Matthews at Cambridge University. Dr. Thouless had discussed with Dr. Matthews, before leaving England, some of the assumptions underlying the sun navigation hypothesis. This hypothesis, as formulated by Matthews, assumes that a bird brought from under cover and released immediately in strange territory necessarily flies at random while it observes the motion of the sun. On the basis of observations over an interval of time, the bird extrapolates the sun along the observed curve of motion and infers east or west displacement from whether local noon comes too soon or too late, and north or south displacement from the elevation of the sun at its highest point. Both Matthews and Kramer have suggested controlling the bird's opportunity to observe the sun at the release point to see how homing orientation is affected. Kramer, in 1952, reported that pigeons were oriented toward home within 40 seconds of the time they were first brought into the sunlight, 30 seconds being spent in the cage for light adaptation and 10 seconds in flight.

Dr. Thouless accepted my suggestion of collaboration in making further homing releases along this line. In our experiments we modified Kramer's procedure in a way previously suggested by him. Instead of keeping the sun-controlled birds in the dark at the release point, we only kept them in the shadow of some opaque object. Thus we were able to eliminate the period of light adaptation in the cages, and exposure to the sun began the moment the bird took flight. The initial orientation of these "no-sun" birds was compared with that of "sun" pigeons exposed to direct sunlight for from 15 minutes to several hours before release.

Seven sets of individual releases were made. They included a total of 96 liberations from six different release points. The use of fire towers provided an opportunity to follow the flight of the birds as long as they could be seen through field glasses. The vanishing points of six birds were not recorded, chiefly due to their perching in trees. Of the remainder, 61

birds vanished toward home and 29 away from home, a statistically significant favoring of the homeward half of the circle (X^2 = 11.38, 1 d.f., P = .0008). The choice of the home half of the circle was significant for the no-sun birds, but not for the sun birds. In the former group 41 vanished toward home and 13 in the wrong half of the circle, and for the sun group there were 20 toward and 16 away from home.

Our main object, however, was to gather information on how soon homeward orientation was apparent rather than whether it could be seen at the vanishing point. After the first experiment, we began taking the birds' bearings after specific intervals of flight, using 10, 20, and 60 seconds on the first occasion, and 10, 20, and 40 seconds thereafter. The results of the 10 second bearings showed that for both the no-sun and sun conditions the direction of the bird from the tower after this interval of flight was related in a statistically significant manner to its bearing after 40 seconds as well as when it vanished from sight. There was no appreciable difference between the two groups.

These results at face value point to the conclusion that whatever the basis of homing orientation, it may come into operation in something less than 10 seconds of flight. And if the no-sun birds were depending upon the sun's motion, as required by the sun navigation hypothesis, they must have made their observations, inferences, and calculations and still have time left to correct the error of the initial stage of random flight by the tenth second of exposure to the sun.

The conclusion that the birds were already homeward bound after 10 seconds can be reached from our series of experiments only if the 96 releases are taken as the units of observation for statistical purposes, and there were indications that this is not statistically justifiable. A study of the departures in different experiments suggests that orientation may be caused by local factors or past experience and therefore the single releases, when a number of them are made from one point, may not be statistically independent of one another. In two of the seven experiments, the birds consistently favored a direction which was not in the home half of the circle. This suggests that a final conclusion may be justified only on the basis of using a large number of randomly selected release points and considering the average effect of each as the unit of observation. This statistical difficulty has been present in all the homing investigations, but it was first clearly recognized as a factor that had to be dealt with in the Duke project. There are more than 200 fire towers within a radius of 200 miles of Durham, and these offer a good opportunity of collecting data that can be assessed on the basis of the average orientation tendency at each release point. An alternative procedure would be to release at one point pigeons

whose lofts lie in different directions to find out if the birds of each group orient accurately toward home.

In our experiments we plan to use both of these methods of coping with the statistical difficulties. Dr. Thouless and I used six different release points in making seven sets of releases, and in three experiments we released birds whose lofts lay in two different directions. The opportunity for collaboration came to an end before the results had reached a point for a final conclusion. In a joint report that is now in the final stages of revision the results are presented as tentatively supporting the conclusion that birds released under the no-sun condition and birds released after exposure to the sun both show homeward orientation within 10 seconds. Because of the importance recently attached to the sun navigation hypothesis, the question of whether this finding can be confirmed on the extreme statistical basis of using each release point as the unit is being asked in the further work now in progress at Duke University.

The present stage of the research began with the arrival, on December 1, of Dr. Kramer's associate, Dr. Ursula v. St. Paul, at Duke University to participate in the project. A number of experimental releases have already been made. In them attention has been focused not only upon the comparison of sun and no-sun birds, but also upon the accuracy of orientation when the release point is north or south of the loft as compared with east or west releases. As far as this work has gone, the sun and no-sun comparisons are in line with those found in the earlier work with Dr. Thouless. It is too soon to say that the earlier findings have been confirmed, but we plan to continue observations under the sun and no-sun conditions in relation to other experimental problems until we have the data from 40 distinct release points for a statistical test of 10-second orientation.

PLANS FOR THE FUTURE

Immediate plans

During the month of February both Dr. Kramer and Dr. St. Paul will be working at Duke on this project. Dr. St. Paul and I have been making our releases with Dr. Kramer's visit in mind in order to have the maximum stock of pigeons available while he will be here. The fact that the German investigators are collaborating on this project resulted from Dr. Kramer's visit in January of last year. He was favorably impressed with the opportunities for homing research in North Carolina during the winter months when their pigeon work must come to a halt in Wilhelmshaven because of bad weather.

Dr. Kramer recently sent us a preliminary report on experiments related to short-distance homing orientation. He presented his results as needing confirmation and extension, and it seems quite likely that he will be chiefly interested in using the opportunity afforded by the many fire towers in North Carolina to conduct further experiments comparing short-distance and long-distance orientation. Thus far the indications are that orientation on first releases at a short distance occurs, but not on a visual basis (even though landmarks are seen clearly by the human observer). It may be occurring instead on some unknown basis, presumably the same one as is used in long-distance orientation. Experiments to amplify his earlier results along these lines will fit in nicely with further releases under the sun and no-sun conditions and with other problems on which information is needed.

After Dr. Kramer returns to Germany, Dr. St. Paul will continue to work with me on the project through the month of May. Beginning while Dr. Kramer is still here and continuing in the months following, we expect to be using birds housed in the lofts of a pigeon fancier in South Carolina for controlled releases. The owner has offered unflown young birds without charge for experimental releases. Also we have had an offer of collaboration from members of a pigeon club in the northeastern section of the United States and from two members of a club in Richmond, one of whom furnished some of the birds that showed outstanding performance last year. We expect, therefore, to be able to deal satisfactorily with the question of statistical significance on the basis of birds released to fly in different directions as well as on the basis of many release points.

Long range plans

The Duke pigeon project is not motivated by any limiting preconceptions of what may be the basis of homing. This does not mean that the research is being done without any working hypothesis, but only that the theoretical concept which provides the motivation for the research is held tentatively as a guiding framework in planning for the long range objectives, not as something we are trying to prove. We are resolved to avoid a mistake that could be well illustrated from the history of the investigation of the homing problem. All too often a hypothesis has been offered on purely logical grounds only to have its promulgator claim prematurely that it had been strongly supported or proved by experimental evidence.

The Duke pigeon work was launched in the Parapsychology Laboratory because the efforts made thus far to explain homing on some specific sensory basis have been unsuccessful. It is conceivable, of course, that a sensory basis of homing may yet be

found, but it is also conceivable that the reason for the repeated failures to solve the mystery may be that research limited to seeking the sensory basis of homing is so narrow in its scope as to exclude the essential principle. For many years, experimental evidence has been accumulated for a capacity in humans to respond to events outside their own organisms under conditions that exclude any known sensory intermediation and which, on the basis of present knowledge, shows no prospect of ever being explainable in sensory terms.

It is a logical question to ask whether this ability for extrasensory perception (ESP) in humans also plays some part in the behavior of other species. The homing of pigeons is an outstanding example of the kind of behavior which might occur on this basis, and it is this possibility which makes the problem an appropriate one for investigation in the Parapsychology Laboratory. On the basis of present knowledge, there is no way to exclude the hypothesis that homing may be an example of responding to an environmental factor (the distant loft) in the absense of any guiding sensory stimulation, and there is at present no alternative sensory hypothesis that fits the facts as well as this. No further scientific justification is required for undertaking a homing research program with the ESP hypothesis in mind. The Duke investigations are taking into account a possible explanation that has been overlooked in other investigations, but they are not excluding any other possibility until it can be eliminated on the basis of crucial tests.

The mere absence at the present time of any adequate sensory hypothesis of homing cannot in itself be considered as evidence for ESP. Before it could be concluded that ESP was established as the basis of homing, it would be necessary to get results in carefully designed and conducted experiments that are adequate to exclude any type of sensory function. The essential requirements of an ESP test of homing are fairly obvious in principle, but they may prove difficult to achieve in practice. Is the bird at its distant release point starting toward some fixed location on the surface of the globe, a spot which it identifies on some yet-to-be-discovered sensory basis, or is it turning toward the familiar loft and surroundings as a situation with which it has purely motivational ties? One way of trying to find out is to move the home to a different location and see whether the pigeon orients toward it or toward the spot where the home was originally. Preliminary efforts with a mobile loft suggest, however, that simply moving the shelter from a familiar environment is not sufficient.

A step to be taken this year is one which follows logically from an experiment, as yet unpublished, that Dr. Kramer and Dr. St. Paul performed last summer in Germany. They housed pigeons in a loft enclosed in an aviary and allowed birds to spend their entire lives inside this enclosure until they were old enough for

test releases. The first time these birds were taken outside this enclosure they were carried under cover to a distance of 200 miles and released one at a time. With the exception of a few of the birds that refused to fly, the pigeons showed homeward orientation at the release point. Some birds were reported as found, and all of these were captured in the direction of home. One pigeon actually returned to Wilhelmshaven to her aviary.

We propose to modify the procedure to make what we call a "walled aviary" experiment. That is to say, the birds will have their loft inside an enclosure with a wire top to give them plenty of fresh air and sunshine, but with opaque walls so that they have no opportunity to become familiar with any object outside the enclosure. The first step will be to see if pigeons so housed will home as did the Wilhelmshaven birds kept in the open aviary. If they do, the next step will be to dismantle the aviary after the next group of birds has been taken out and move it to a spot in the opposite direction from the release point. All traces of home will be erased at the original location. Will the birds now orient toward the visually unrecognizable spot on the globe where the aviary stood before, or will they orient toward the loft and its enclosure in the new location? If the latter should appear to be the case, the experiment would naturally have to be repeated several times with different release points and with different new locations of the walled aviary, some of the releases involving distances of at least 50 to 100 miles. Furthermore, every possible experimental precaution against subjective errors in observation and recording would be taken, as such a result would be revolutionary in its scientific implications. The greatest possible care would be taken against premature conclusions or wrong interpretations of the facts. If results such as would be predicted on the basis of the ESP hypothesis were obtained, it is not to be expected, of course, that there would be immediate and unanimous agreement on how the findings should be interpreted. There could scarcely be any doubt, however, that such findings would represent an important scientific discovery and that they would provide a new point of departure for the study of principles of navigation in animals.

Dr. Kramer and I have discussed a plan he proposed that would serve the same general purpose as the walled aviary experiment. His plan would involve more elaborate preparations, however, and it seems logical to find out first if the problem can be dealt with by means of the walled-aviary design or by some better method that may be found. For the sake of brevity, Dr. Kramer's plan will not be developed in detail but the basic idea is to experiment with pigeons housed in a loft aboard a ship.

On the side of general research method, we hope to explore the possibilities of observing homing orientation in pigeons before they are released. Dr. Kramer wrote me in the summer that

he and Dr. St. Paul had successfully obtained orientation with the bird in a very large cage of light material. After the first successes, however, the results became discouraging and the objective was put aside because of other pressing research activities. Dr. St. Paul brought the large cage to America, and we expect to make further attempts to observe homing orientation of birds in it during the spring months. Our efforts will be, first, to use the same procedure as was tried at Wilhelmshaven to see if we can repeat their original results, and if this fails to vary the procedure in any way that offers any hope of success. Different investigators have reported efforts to study homing without releasing the birds on each occasion. So far, all these efforts have been disappointing. The advantages which such an advance in methodology would provide are so great that the search should not be abandoned as long as likely possibilities remain to be tried.

REPORTS AND PUBLICATIONS

Pratt, J. G. The Homing Problem in Pigeons, J. Parapsychology, 17, (1953), 6-23.

Pratt, J. G. An Investigation of Homing Ability in Pigeons without Previous Homing Experience. (Awating publication.)

Pratt, J. G. Flight Behavior of Pigeons Housed in a Mobile Loft. (Unpublished manuscript.)

Pratt, J. G. and Thouless, R. H. Homing Orientation in Pigeons in Relation to Opportunity to Observe the Sun before Release. (Experimental report in final stages of revision.)